Competition

Moderator:

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ADDITION OF SULFOMETURON METHYL TO FALL SITE PREPARATION TANK MIXES IMPROVES HERBACEOUS WEED CONTROL

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Abstract— A total of 12 herbicide treatments were applied to a recently harvested forest site in Winston County, MS. All treatments were representative of forest site preparation tank mixtures and were applied early September, 1999. Three ounces of Oust7 were included in two of the tank mixes, and 19 ounces of Oustar7 were included in two of the mixes. All treatments were applied with a CO_2-powered backpack sprayer to simulate aerial application at 10 gpa. In May, June, July, and August of 2000, treatment plots were evaluated for herbaceous competition control. During October, 2000, plots were evaluated for woody stem control based on a comparison with pre-treatment measurements. In May 2000, herbaceous species had reduced the average percent clear ground to 42-62 percent in plots without Oust or Oustar while those plots with the products added had 94-97 percent clear ground. Untreated areas had only one percent clear ground by this rating time. Percent clear ground continued to decrease to 10-15 percent in July for plots without Oust or Oustar while plots were 83-94 percent clear in treatments with the product. By August, plots with the Oust were 65-80 percent clear and those with Oustar were 57-92 percent clear whereas plots without the products were 5-13 percent clear. Both Oust and Oustar provided excellent herbaceous weed control for 12 months following application in this study. Oustar provided slightly better control than the Oust.

INTRODUCTION

In establishing a new stand of trees, the competition from herbaceous weeds is a significant factor in the initial survival and growth of planted seedlings. The current conventional approach to this problem is to apply a release treatment over the top of the planted seedlings in either a broadcast or banded pattern. While this competition problem is most often addressed in pine management, it is a noteworthy in hardwood plantation establishment, also. Interest has been expressed in the potential for a site preparation treatment which would also provide first year herbaceous competition control for pine seedlings.

OBJECTIVES

The objectives for this study were as follows:

1) To evaluate the efficacy of Oust and Oustar for herbaceous weed control the year following site prepapplication.
2) To evaluate various tank mixtures for control of competing woody vegetation during site preparation

METHODS

The study was installed in Winston County, MS on land owned by The Timber Company. The previous stand had been mixed pine-hardwood and had been harvested in October, 1998. The soil was a clay loam with a pH = 5.6. A total of 12 herbicide treatments were applied on September 8, 1999. A complete list of the treatments is found in table 1.

Herbicide treatments were applied to with a CO_2-powered backpack sprayer with a total spray volume of 10 gpa. Each treatment and an untreated check were replicated three times in a completely randomized design.

Prior to treatment, a woody stem count was completed on each plot, and stems were recorded by species and height class. An ocular estimate of brownout was completed at 6WAT, and plots were assessed in October 2000 for any living woody stems. During May, June, July, and August, herbaceous cover was estimated ocularly in the plots. All data were subjected to ANOVA and specific tests to separate means.

RESULTS

The results of herbaceous competition control evaluations can be found in tables 2, 3, and 4. When compared to untreated areas, the herbicide treatments all exhibited control on herbaceous weeds. However, by July, those treatments without Oust or Oustar generally had 15 percent or less clear ground while those with Oust or Oustar generally had more than 80 percent clear ground (table 2). The addition of either Oust or Oustar provided excellent herbaceous weed control throughout the growing season.

Percent grass cover was relatively low on the area with scattered *Panicum* spp., *Carex* spp., and *Andropogon* accounting for the vast majority of this type vegetation. Only the *Andropogon* invaded the plots with Oust or Oustar (table 3). Overall, grass/sedge was not a major competitor on this site.

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Broadleaf weeds were a major source of competition on this site. The site preparation mixes without Oust/Oustar did not differ from the untreated check in percent broadleaf coverage (table 4). The treatments with Oust or Oustar did an excellent job of controlling the broadleaves on this site until August which was 11 months after application. Even then, control was still good with generally less than 33 percent of the plot covered by broadleaves, although one replication in Treatment 11 did have higher infestation. The principal species on the site were fireweed (*Erechtites hieracifolia*), woolly croton (*Croton capitatus* var. *capitatus*), common ragweed (*Ambrosia artemisifolia*), and common pokeweed (*Phytolacca americana*). The woolly croton was not a problem until late in the growing season and accounts for much of the increased coverage in Oust/Oustar plots in August (table 4).

A wide variety of woody species occurred on this site, but the majority of stems were either sweetgum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), or persimmon (*Diospyros virginiana*). There was no significant difference among any of the treatments in the control of sweetgum or persimmon, and only one treatment varied significantly in the control of red maple (table 5). Overall control of woody species was excellent as noted by the “Total” column in table 5. This percent is for all stems of all species. The more common of the “less frequent” species included loblolly pine (*Pinus taeda)*, winged elm (*Ulmus alata*), water oak (*Quercus nigra)*, cherrybark oak (*Q. pagoda)*, willow oak (*Q. phellos*), post oak (*Q. stellata*) and southern red oak (*Q. falcata*). Control for these species can be found in table 6. As might be expected, these species all generally increased their number of stems per acre in the untreated plots (table 5 and 6).

SUMMARY

Overall, the site preparation treatments in this study did an excellent job. The treatment areas were generally free of woody competition can could be planted easily.

Table 1—List of treatments in 1999 Fall Oust/Oustar site preparation field trials –MS

Treatment No.	Herbicides Rates/A.[a]
1	6 QTS KRENITE + 20 OZ CHOPPER + 1 QT TL90
2	4 QTS KRENITE + 20 OZ CHOPPER + 1 QT TL90
3	4 QTS KRENITE + 20 OZ CHOPPER + 1 QT TL90
4	4 QTS KRENITE + 16 OZ CHOPPER + 1 OZ ESCORT 1 QT TL90
5	4 QTS KRENITE + 20 OZ CHOPPER + 1 QT ACCORD SP + 1 QT TL90
6	5 QTS ACCORD SP + 16 OZ CHOPPER
7	1 QT ACCORD SP + 48 OZ CHOPPER + 1 QT TL90
8	1 QT ACCORD SP + 1 OZ ESCORT + 24 OZ CHOPER + 1 QT TL90
9	TMT #6 WITH 3 OZ OUST
10	TMT #7 WITH 3 OZ OUST
11	TMT #6 WITH 19 OZ OUSTAR
12	TMT #7 WITH 19 OZ OUSTAR
13	UNTREATED

[a] all rates are expressed as actual product.

The addition of Oust or Oustar to the treatments provided excellent herbaceous weed control for the entire growing season following application. Oustar did provide slightly better control than Oust, but this could be due to the species involved. Land managers now have an option for first year herbaceous competition control which could avoid release operations.

Table 2— Average percent clear ground in 1999 Fall Oust/Oustar site prep field trials-MS

	Time of Evaluation			
Treatment No.	May	June	July	August
	---------------Percent--------------------			
1	53b[a]	37b	10b	7c
2	42b	32b	13b	10c
3	62b	37b	18b	13c
4	42b	30b	13b	7c
5	53b	40b	15b	8c
6	47b	30b	10b	5c
7	43b	28b	10b	7c
8	58b	40b	13b	7c
9[b]	95a	91a	87a	80a
10[b]	97a	95a	93a	65b
11[c]	94a	90a	83a	57b
12[c]	96a	94a	94a	92a
13	2c	1c	0c	0c

[a.] Values in column followed by the same letter do not differ at P = 0.05
[b.] Treatments with 3 ounces Oust/A
[c.] Treatments with 19 ounces Oustar/A

Table 3-- Average percent grass cover in 1999 Fall Oust/Oustar field trials-MS

	Time of Evaluation			
Treatment No.	May	June	July	August
	-------------Percent--------------			
1	2	2	5	7
2	2	2	3	5
3	2	2	4	5
	4	2	2	3
5				
5	2	2	4	7
6	2	2	4	7
7	2	4	6	7
8	2	3	5	7
9[a]	0	0	0	1
10[b]	0	0	0	1
11[b]	0	0	0	1
12[b]	0	1	1	2
13	6	7	12	18

[a.] Treatments with 3 ounces Oust/A
[b.] Treatments with 19 ounces Oustar/A

Table 4-- Average percent bradleaf cover in 1999 Fall Oust/Oustar field trials-MS

Treatment No.	Time of Evaluation May	June	July	August
	-------------------Percent---------------			
1	37b[a]	53b	67b	85b
2	50b	62b	68b	83b
3	43b	58b	67b	80b
4	53b	67b	70b	87b
5	43b	58b	67b	83b
6	53b	67b	75b	87b
7	57b	68b	78b	90b
8	40b	57b	67b	80b
9[b]	1a	2a	5a	20a
10[b]	1a	2a	2a	33ab
11[c]	2a	3a	6a	40ab
12[c]	1a	1a	2a	7a
13	50b	53b	53b	67b

[a.] Values in column followed by the same letter do not differ at P = 0.05

Table 6—Average percent stem reduction in "other" species found in 1999 Fall Oust trials–MS

Trt. No.	LLP	WAD	WIE	Species[a] CBO	WIO	POO	SRO
	--------------------------------Percent	---------------------------------					
1	-100[b]	-100	+30	*	*	*	*
2	-100	-100	+85	-100	-100	-100	*
3	-100	-100	-46	-100	-100	-100	-100
4	*[c]	-100	-100	*	*	*	*
5	*	*	nc[d]	-85	*	-100	*
6	-100	*	-30	-100	-100	-100	-100
7	-23	*	-77	-100	*	*	-100
8	-58	-100	-100	-100	-100	-100	-100
9	-88	+100	-100	-100	-100	-100	-100
10	-10	-100	*	-100	-100	-100	-100
11	+33	+30	-89	-70	*	-57	*
12	-57	nc	-37	-100	-100	-100	-100
13	*	+700	+143	+30	nc	+31	+233

[a.] LLP = loblolly pine, WAO = water oak, WIE = winged elm, CBO = cherrybark oak, WIO = willow oak, POO = post oak, SRO = southern red oak
[b.] Negative values indicate reduction in number of stems
[c.] Insufficient stems for evaluation

Table 5— Average percent stem reduction of principal species in 1999 Fall Oust field trials-MS

Treatment No.	Herbicides[a]	Species[b c] SWG	REM	PER	Total
		------------Percent	--------------------		
1	Krenite + Chopper (6+20)	100a	-100a	-100a	-85ab
2	Krenite + Chopper (4+20)	-100a	-100a	-85ab	-90a
3	Krenite + Chopper (4+24)	-100a	-100a	-100a	-98a
4	Krenite + Chopper + Escort (4+16+1)	-100a	-100a	-100a	-94a
5	Krenite + Chopper + Accord SP (4+20+1)	-100a	-100a	-100a	-95a
6	Accord SP + Chopper (5+16)	-100a	-100a	-100a	-93a
7	Accord SP + Escort + Chopper (1+48)	-100a	-100a	-100a	-88a
8	Accord SP + Escort + Chopper (1+1+24)	-100a	-100a	-100a	-93a
9	Trt. #6 + 3 oz Oust/A	-89a	-100a	-100a	-93a
10	Trt. #7 + 19 oz Oust/A	-100a	-100a	-100a	-90a
11	Trt. #6 + 3 oz Oustar/A	-100a	-80b	-100a	-68b
12	Trt #7 + 19 oz Oustar/A	-100a	-100a	-100a	-94a
13	Untreated	+23b	+260c	+67c	+51

[a.] Krenite and Accord SP = quarts/A., Chopper and Escort = ounces/A.
[b.] SWG = sweetgum, REM = red maple, PER = persimmon
[c.] Values followed by the same letter in a column do not differ at P = 0.05

FIFTH-YEAR HEIGHT AND SURVIVAL OF LOBLOLLY PINE ACROSS TENNESSEE FOLLOWING VARIOUS SILVICULTURAL TREATMENTS

Lyle E. Taylor and John C. Rennie[1]

Abstract—Loblolly pine (*Pinus taeda*) was planted at nine experiment stations located across Tennessee in 1993-94 and 1994-95 using a customized fractional factorial design. Two sites, good and poor, were chosen on each experiment station to compare effects of soil productivity on height and survival. At each site, three treatments were evaluated: spacing (8X8, 8X10, and 10X10 feet), post-planting herbicide application after spring green-up (2.0 oz/ac Oust and 4.0 oz/ac Arsenal), and fertilization at planting (three, 9 gm, 22-8-2 fertilizer tablets per tree). Height measurements and survival counts were taken after the fifth growing season. The least square estimates of mean height and survival over all treatments and sites after five growing seasons were 11.9 feet and 83 percent, respectively. Results indicate that herbicide application increased tree height by 8 percent (11.4 vs. 12.4 feet). Survival increased 13 percent (77 vs. 87percent) when herbicide was used. Significant differences ($P < 0.05$) among experiment stations were found for height and for survival. Mean height estimates ranged from 9.5 feet at the West Tennessee Experiment Station to 13.5 feet at Ames Plantation and the Highland Rim Forestry Station. Survival ranged from 59 percent at the Dairy Experiment Station to 99 percent at the Highland Rim Forestry Station. No significant differences were found between good and poor sites. The herbicide treatment increased survival significantly more ($P < 0.05$) on poor sites than on good sites.

INTRODUCTION

The native range of loblolly pine (*Pinus taeda*) extends into only 13 of Tennessee's most southerly counties (see p. 497, Baker and Landgon 1990). However, it has been planted extensively in the state. These plantations were reflected in the number and distribution of U.S.D.A. Forest Service, Forest Inventory and Analysis plots with loblolly pine in the late 1980's (see p. 7, Beltz and Bertelson 1990). More evidence comes from the two most recent inventories of Tennessee's forest resources (table 1). The area of loblolly plantations was about 280,000 acres in the late eighties, increasing to about 385,000 acres in the late nineties (U.S.D.A. Forest Service 2001). The areas reported above are for loblolly pine, not loblolly-shortleaf pine as published in the state statistics. This increase of approximately 105,000 acres is about equally divided between forest industry and private non-industrial ownership. Thus, loblolly pine is an important species in Tennessee even though it has a limited native range in the state.

In the early 1990's, Dr. Edward Buckner and Mr. John Mullins of the University of Tennessee Department of Forestry, Wildlife and Fisheries, conceived a study to help Tennessee landowners more effectively grow loblolly pine. Specifically, this study was designed to determine the effects of various silvicultural treatments on the establishment and growth of loblolly pine on various sites commonly found in Tennessee.

METHODS

Tennessee has a wide range of growing conditions across its many diverse physiographic regions. For the results to be widely applicable, loblolly pine was planted at nine experiment stations located in five physiographic regions (figure 1). A good site and a poor site, based on the performance of agronomic crops, were chosen on each location (experiment station) to compare effects of soil productivity on height and survival. Only three sites were in forest cover immediately before study establishment: the good site and the poor site at the Forestry Experiment Station (Oak Ridge) and the poor site at Ames Plantation. The other sites had been in agriculture, including corn (2 sites), soybeans (2), alfalfa (2) and pasture (9).

Three treatments were evaluated: spacing (8X8, 8X10, and 10X10 feet), fertilization at planting (three, 9 gm, 22-8-2 fertilizer tablets per tree (22-8-2)), and post-planting

Table 1—Area of Tennessee forests and of pure loblolly pine plantations in 1989 and 1999 (USDA Forest Service 2001)

	Area (thousands of acres)	
	1989	1999
Timberland	13,265	13,965
Loblolly plantations	280.2	385.6
Public	16.6	15.7
Forest Industry	184.6	235.4
Private non-industrial	79.0	134.5

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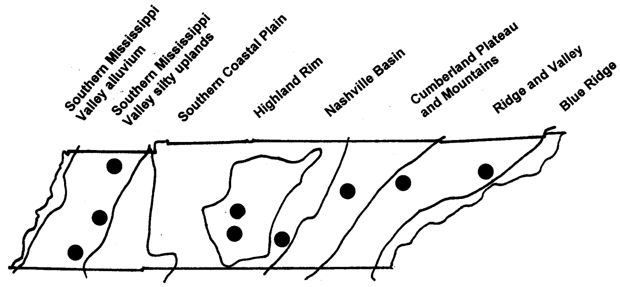

Figure 1—Physiographic regions of Tennessee and Agricultural Experiments Stations that served as study locations. In the Southern Mississippi Valley silty uplands from south to north, Ames Plantation (AMES), West Tennessee Experiment Station (WTES), and Martin Experiment Station; in the Nashville Basin from south to north, the Dairy Experiment Station (DES), and the Middle Tennessee Experiment Station (MTES); in the Highland Rim, the Highland Rim Forestry Station (HRFS); in the Cumberland Plateau and Mountains, the Plateau Experiment Station (PES); in the Ridge and Valley from west to east, the Forestry Experiment Station (FES) and the Tobacco Experiment Station (TES).

herbicide application after spring green-up (2.0 oz/ac Oust and 4.0 oz/ac Arsenal). The study was installed in 1993-94 and 1994-95 using a customized fractional factorial, incomplete block design. The first year's installations had nine plots per site, while in the second year there were 10 or 11 plots per site. Height and survival obtained after the fifth growing season are presented in this paper. A significance level of 0.05 was used. SAS PROC MIXED was used to analyze the data. Significant differences were tested using the PDIFF option.

RESULTS AND DISCUSSION

The least square estimates of survival and height over all treatments and sites after five growing seasons were 83 percent and 11.9 feet, respectively. Survival increased from 77 percent to 87 percent with herbicide application. Tree height increased from 11.4 feet to 12.4 feet when herbicide was used. Effects of herbicide on survival and height were statistically significant.

Significant differences among experiment stations were found for survival and for height. Survival ranged from 99 percent at the Highland Rim Forestry Station to 59 percent at the Dairy Experiment Station (figure 2). Survival at the Dairy Experiment Station was significantly lower than at all other sites. Most experiment stations had a small number of trees damaged by deer or winter weather. Damage due to snow and ice in the winter between the fourth and fifth growing season was more extreme at the Plateau Experiment Station. While 79.1 percent of the trees survived, only 59.2 percent were free of damage at this location.

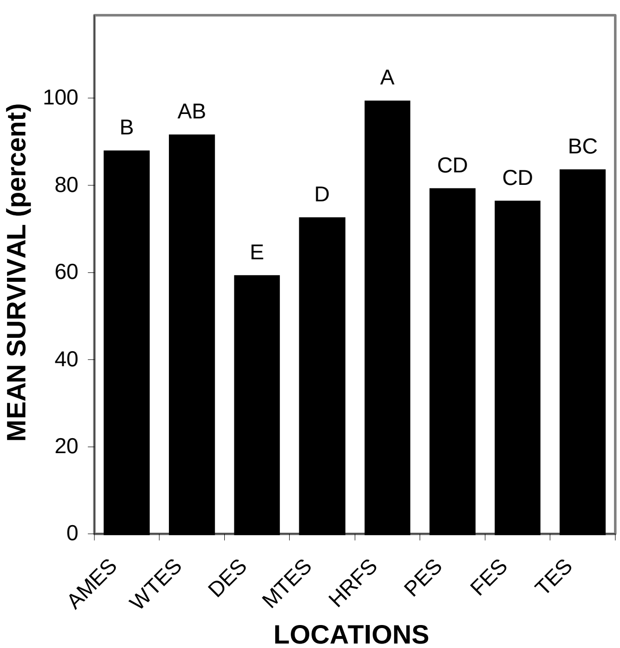

Figure 2— Least square estimates of mean survival for each location. Locations with the same letter were not significantly different (P > 0.05).

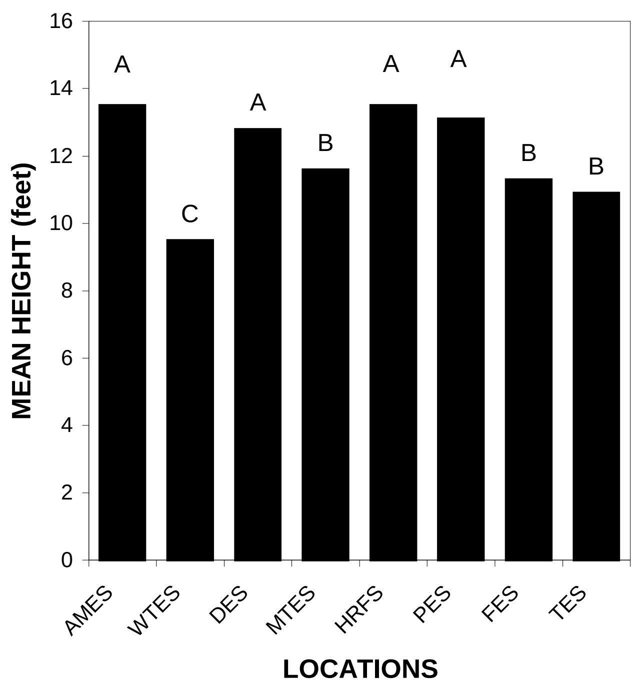

Figure 3— Least square estimates of mean height for each location. Locations with the same letter were not significantly different (P > 0.05).

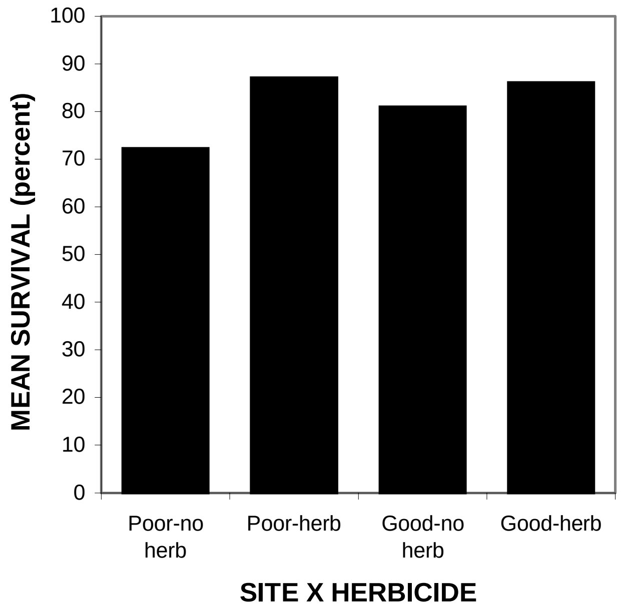

Figure 4— Least square estimates of mean survival for combinations of site and herbicide application.

Mean height estimates ranged from 13.5 feet at Ames Plantation and the Highland Rim Forestry Station to 9.5 feet at the West Tennessee Experiment Station (figure 3). Three nonoverlapping groups were found for height. Group one included Ames Plantation (13.5 feet), the Dairy Station (12.8), the Highland Rim Forestry Station (13.5) and the Plateau Station (13.1). Group two included the Middle Tennessee Station (11.6), the Forestry Station (11.3), and the Tobacco Station (10.9). Finally, group three consisted of only the West Tennessee Station (9.5). The height at the West Tennessee Station was low because the mean height for the poor site was only 6.5 feet. However, that for the good site was 12.5 feet.

The herbicide treatment increased survival significantly more on poor sites than on good sites (figure 4). Survival increased by 14.8 percentage points when herbicides were used on the poor sites as compared to an increase of 5.1 percentage points on the good sites. No such effect was found for height.

Although no significant differences were found between good and poor sites, some observations may be useful to others. Sites were selected and assigned to “good” or “poor” based on the performance of agronomic crops in consultation with the Superintendent of each experiment station. In the process of analyzing this study, we determined the soil type or types from soil surveys, and the loblolly pine site index and capability class based on soil type(s) for each site. There was little relationship between site index and capability class, and “good” or “poor” site. At two locations, the poor site had a higher site index than the good site, while at three locations both sites had the same site index. One site in the latter group was the Tobacco Experiment Station where survival and height were considerably higher on the poor site as compared to the good site.

RECOMMENDATIONS

Based on five years results, establishment and growth of loblolly pine can be successful throughout most of Tennessee. The treatment that showed promise for improving survival and height growth is the use of herbicides in association with planting. Their use on poor sites appears to have a greater effect on improving survival than on good sites. One factor limiting the success of loblolly pine is the occurrence of snow and ice frequently enough and in sufficient amounts to cause considerable mortality and damage.

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THIRTEEN YEARS LOBLOLLY PINE GROWTH FOLLOWING MACHINE APPLICATION OF CUT-STUMP TREATMENT HERBICIDES FOR HARDWOOD STUMP-SPROUT CONTROL

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Abstract—Thirteen year growth results of 1-0 out-planted loblolly pine seedlings on non-intensively prepared up-land mixed pine-hardwood sites receiving machine applied cut-stump treatment (CST) herbicides onto hardwood stumps at the time of harvesting is presented. Plantation pine growth shows significantly higher growth for pine in the CST treated plots compared to non-CST plots. Planted pine survival, diameter, height, stem-volume, and total volume per plot was higher in CST treated plots when compared to non-treated plots. Total pine volume in CST treated plots is as high as 125 percent higher than in non-treated plots. Pine growth advantage in CST treated plots has existed since time of planting. CST herbicides were selectively applied to the cut surface of hardwood stumps for stump-sprout control. The selective application of CST herbicides was combined with operation of a drive-to-tree type feller-buncher tree-harvester.

INTRODUCTION

Forest regeneration to pure pine stands after clearcut harvesting mixed pine-hardwood stands is a common forest management objective in the Southern United States. Competition from undesirable woody and herbaceous vegetation reduces pine survival and growth however. Pine volume after five years with competition control for both herbaceous vegetation and woody plants averaged about fourfold more than pine stands with no competition control for thirteen plantation study sites (Miller and others 1991). With only woody plant control pine volume increased by an average of 67 percent and with herbaceous control only pine volume increased by 171 percent. A significant portion of the woody competition may be hardwood occurrence from stump sprouting. Two conditions favorable for hardwood stump sprouting are low stump height and harvest of immature trees (Smith 1962). Those two conditions commonly result with mechanized harvesting using feller-buncher tree harvesters, especially when harvesting trees for pulp. Sprouts of hardwood stump origin are more vigorous than from seedling-origin (Smith 1979). Furthermore, the growth advantage of hardwoods of stump-sprout origin is maintained into later years (Smith 1962). After 12 yrs, diameter and height growth of stems of stump origin were almost twice that of stems from seedling origin for some hardwoods of seedling origin (Smith 1979). Vidrine and Adams (1993) reported hardwood stump sprouting had occurred on 67 percent of hardwood stumps two years after harvesting a mixed pine-hardwood stand. Vidrine also reported six year loblolly pine survival and growth results resulting from machine applied CST herbicides and the description of the sprayer system. Pine survival and growth in the CST plots were significantly higher than in control plots receiving no CST herbicides.

The sprayer system was adapted for use on a drive-to-tree type feller-buncher tree harvester to apply the CST herbicide immediately after cutting each hardwood tree. CST herbicides must be applied shortly after cutting to be effective (Wenger 1984). The sprayer system used in Vidrine's study consisted of an operator-controlled 12-volt direct current powered pump and full cone type spray nozzle with the nozzle mounted onto the feller-buncher harvester shear head. Immediately after shearing a hardwood tree the feller-buncher operator sprayed the cut stump surface using the sprayer system with a CST herbicide. This paper, using remeasured data from the same study as Vidrine, reports follow-up pine growth results after thirteen growing seasons as the stand nears the time for a first thinning harvest.

METHODS

The site is located in north central Louisiana in southern Lincoln Parish. Soils are Sacul (Aquic Hapludults) and Bowie (Plinthic Paleudults) silt loams with an estimated site index of 85 feet for loblolly pine at age 50 year (Kilpatrick and others 1996). The mixed pine-hardwood stand consisted of loblolly pine (*Pinus taeda L.*) and the hardwoods consisted principally of oak (*Quercu* spp), hickory (*Carya* spp), maple (*Acer* spp), and sweetgum (*Liquidambar styraciflua*). The site was clearcut harvested in July and August, 1985, with whole trees processed for fuel and pulp chips using an in-woods chipper, and replanted to pine the following winter. Trees were mechanically felled using a drive-to-tree type feller-buncher equipped with a double-acting shear head and whole tree skidding was performed using four-wheel-drive rubber-tired grapple skidders. Other than applying CST herbicide to hardwood stumps to control

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stump sprouting with the feller-buncher harvester, no mechanical, chemical, control burn, or other site preparation treatment was applied. The CST herbicides were machine applied at the time of felling while performing the clearcut harvest. Fifteen 0.2 ac CST test plots established consisted of three replicates of five treatments for the randomized block experimental design. The five CST treatments for the study consisted of a control (no CST herbicide applied), picloram (Tordon 101R), triclopyr-ester (Garlon 4), triclopyr-amine (Garlon 3A), and dicamba (Banvel CST)—all labeled for cut-stump-treatment. The freshly cut hardwood stump surfaces were machine-sprayed with one of the undiluted CST herbicides to include a thorough wetting of the cambial area in accordance with CST-label instructions. Bareroot 1-0 loblolly pine seedlings were outplanted in the 0.2-acre feller-buncher-sprayer treatment plots in February, 1986, on a 8 by 8-ft spacing using a 7 by 7 array for a total of 49 planted pines in each measurement plot of area 0.072 acre. Each planted pine was marked by a flagpin at the time of planting and at year ten aluminum tags were nailed to the remaining trees of the 49 originally planted. Tag labeling consisted of plot number, tree number, and the CST treatment. Performance evaluation of the process was based on 13-year growth measurements of pine total height, DBH, associated calculations of stem volume of individual trees, the resulting total planted pine volume in each plot determined by summing individual stem volumes, and hardwood stem count. Total tree volumes were calculated according to equations by Clark and Saucier (1990) from DBH and total tree height measurements. Duncan's New Multiple Range Procedure was used for mean separation for planted pine survival, height, diameter, stem volume, total volume in each plot, and number hardwoods present in each plot for the five-treatment three-replicate randomized block experimental design.

RESULTS AND DISCUSSION

Pine survival and growth on all machine-applied herbicide CST plots was significantly higher than pine growth on the control plots after thirteen growing seasons although there were differences within herbicide treatments (table 1).

Table 1—Planted pine survival, growth, and hardwood/ volunteer pine competition of machine-planted DST herbicide treated plots after thirteen growing seasons[1]

	Plot Means						
Treatment	Survival (pct)	Ht. (ft)	DBH (in)	Stem Volume (ft^3)	Pine Volume (ft^3/ac)	Hardwoods (#/ac)	Volun. Pines (#/ac)
Picloram	77a	42a	6.3bc	3.9a	2030a	1240bc	429
Tri-a[2]	64abc	40bc	6.5ab	4.0a	1733ab	833d	371
Tri-e[3]	61bc	41b	6.7a	4.2a	1725ab	1181bcd	389
Dicamba	68ab	38c	6.2c	3.3b	1538b	2157ab	399
Control	46d	39c	5.6d	2.9b	904c	2343a	403

[1]Columnar means followed by the same letters are not significantly different at the 95-percent probability level, according to the Duncan's New Multiple Range Test.
[2]Tri-a is triclopyr amine
[3]Tri-e is triclopyr ester.

Mean number hardwoods and number of volunteer pines are also reported in table 1. Pine survival, height, and total pine volume were significantly higher in the picloram CST plots than other treatment plots. Pine diameter and stem volume were highest for the triclopyr-ester treated plots. Planted pine survival, height, diameter, stem volume and total plot volume were lowest in the control plots receiving no herbicide treatment to control hardwood stump sprouting. Mean total pine volume ranged from a low of 904 ft^3/acre in the control plots receiving no CST herbicide to a high of 2030 ft^3/acre for the picloram CST herbicide treatment. Plot volume, which accounts for the individual stem volumes and survival, was consistent with those factors. The inverse relationship between hardwood competition and pine growth reported by Langdon and Trousdell (1974) is supported by the results. Number of hardwood stems was the highest in the control plots at 2343 stems/acre with associated pine volume at 904 ft^3/acre while the picloram and triclopyr amine CST plot had the lowest hardwood stem count of 1240 and 833 stems/acre and the highest pine volume at 2030 and 1733 ft^3/acre, respectively. The dicamba plots had the highest hardwood stem count of the CST plots at 2157 stems/acre and lowest associated planted pine volume of the CST plots at 1538 ft^3/acre. There were almost as many volunteer pines on the plots as there were planted pine at thirteen years but the volunteer pine were generally smaller in diameter and height than the planted trees. Seed source of the volunteer pine was probably from the pines harvested at the time this study was established and from neighboring pine trees in the area. Statistical analysis was not applied to the mean number volunteer pines per plot since their occurrence was independent of the CST procedures applied. The occurrence of hardwood in the CST plots was generally not of stump sprout origin with the exception of the dicamba treatment. After two growing seasons, hardwood stump sprouting on picloram and triclopyr CST plots was only about 6 percent, while on the control plots stump sprouting was 67 percent, as reported by Vidrine and Adams (1993). Stump sprouting on the dicamba treated plots after two years was about 20 percent and may have contributed to the high number of hardwoods and low pine volume at age thirteen.

CONCLUSIONS

Results of this study indicate that machine application of CST herbicides during harvest to control hardwood stump sprouting is effective at suppressing hardwood competition thus allowing increased production of planted loblolly pine plantations. Pine volume on picloram treated plots was highest of all treatments at 2.25 times that of pine volume on non-CST treated plots after thirteen years growth. Pine volume was not significantly different for the picloram and the triclopyr treatments. Pine volume on the dicamba treated plots was lowest of the CST treatments but still 1.70 times that of the control plots. The 13-year results agree with the results from six-year growth, pine survival, diameter, and height in the picloram and triclopyr treated plots were significantly higher than for the other treatments (Vidrine and Adams 1993) indicating the benefits of the two CST treatments are maintained. Follow up studies of using machine applied CST herbicides for stump sprout control should be performed using sawhead equipped feller-bunchers as commonly used today rather than the shear type used in this study. Also, machine application techniques should be developed where the herbicide is applied only to the cambial area of the cut rather than wetting the entire cut surface to reduce the amount of herbicide required. For trees 3-inches dbh and larger, the recommended treatment area is the cambial area (USDA Forest Service 1994).

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WEED CONTROL AND SEEDLING PERFORMANCE USING OUST, VELPAR, AND VELPAR+OUST IMPREGNATED DIAMMONIUM PHOSPHATE

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Abstract—Technology that combines herbicide and fertilizer into one treatment thereby reducing application costs while enhancing growth is needed. Four clean and well-prepared sites in TX, MS, and AL were tested. Study objectives were to evaluate the effectiveness of diammonium phosphate (DAP) impregnated with Oust, Velpar, or Velpar+Oust for herbaceous weed control and newly planted loblolly pine (*Pinus taeda* L.) seedling growth. In 1999, treatments were applied early post weed-emergence to 60percent bare ground in East TX. Impregnated DAP provided about 38percent less competitor control than separate liquid and fertilizer applications at similar rates. Best seedling survival and growth resulted from liquid sprays of Oust and Velpar+Oust. Treatments in 2000 were applied to bare ground in TX, MS, and AL. Weed control for Oust-impregnated DAP, Velpar+Oust-impregnated DAP, Velpar impregnated on 250 pounds of DAP and liquid herbicide treatments was similar 120 days after treatment. Seedling survival and growth for impregnated DAP treatments was similar to that for conventional herbicide and DAP treatments. Growth trends are preliminary and will be followed. Drought probably influenced study results.

INTRODUCTION

Numerous studies spanning a variety of sites and conditions have demonstrated the effectiveness of vegetation management and fertilization at increasing loblolly pine growth. Consequently, the intensive culture of loblolly pine relies heavily on technologies of weed control and supplemental nutrition.

Currently, managers treat newly planted loblolly pine seedlings for herbaceous weed control and nutrient deficiencies in two separate applications and incur two application costs. Technology that combines multiple treatments, thereby reducing the number of passes and application costs per acre, is needed. The development of a weed-and-feed technology potentially combines two technologies, herbaceous weed control and fertilization, in a single application. The weed-and-feed approach has been tested in young pine stands less than three years old and other stands between ten and twenty-five years old (Shiver et al. 1999). Results suggest growth from the fertilizer impregnated with hexazinone (Velpar) was higher than either treatment separately as well as the untreated check. The usefulness of Oust, Velpar, and Velpar+Oust impregnated DAP applied over the top of newly planted seedlings needs to be tested. The purpose of this report is to present the weed control of liquid herbicide and herbicide impregnated DAP treatments and the resultant seedling growth. The objective of the 1999 test was to compare weed control and seedling performance among a post-emergence application of (1) conventional liquid herbicides, (2) the same conventional herbicides impregnated on 125 pounds of DAP, (3) 125 pounds of DAP only, and (4) neither herbicide nor DAP (Check). Specific rates of test treatments are presented in table 2. The objective of the 2000 study was to assess weed control and seedling performance among a pre-emergence application of (1) conventional liquid herbicides, (2) the same conventional herbicides impregnated on 125 or 250 pounds of DAP, (3) 125 pounds of DAP only, and (4) neither herbicide nor DAP (Check). Specific rates for test treatments are presented in tables 4 and 5.

METHODS

One location in 1999 and three locations in 2000 were tested. All four tests were clean of harvesting slash and free of established rootstocks. A summary of the sites is presented in table 1.

In TX, 1999 treatment plots were approximately 56 feet X 80 feet and consisted of seven trees in each of eight rows or 56 seedlings. In 2000, treatment plots were 64 feet X 80 feet with eight trees in each of eight rows or 64 seedlings. In MS and AL treatment plots were approximately 80 feet X 96 feet and spanned eight rows each with at least 10 seedlings. Treatment plots were surrounded by a 10 feet, untreated buffer strip.

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Table 1—A summary of test sites

Location	Beulah, TX	Diboll, TX	Picayune, MS	Whitfield, AL
Established	1999	2000	2000	2000
Physiography	UCP[a]	UCP[a]	LCP[a] flatwoods	LCP[a] interior flatwoods
Soil	silt loam	sandy loam	sandy clay loam	silty clay loam
Harvested	Dec-97	Sep-98	Dec-98	Aug-98
Site Prep1	9/98 Ars+Gar 4[b] 14oz+2qt	9/99 Ars+Gar 4[b] 16oz+2qt	10/99 shear & rake	12/98 burn
Site Prep2	10/98 burn	10/99 mulch	11/99 double bed	7/99 Chop+Esc+Acc[b] 40oz+1oz+1qt
Site Prep3	10/98 subsoil	10/99 subsoil	12/99 burn windrows	12/99 subsoil
Planted	Feb-99	Feb-00	Jan-00	Jan-00
Treated	22-Mar-99	9-Mar-00	16-Mar-00	3-Apr-00
Percent Cover	40	1	1	1
Treatments	Broadcast	Broadcast	Broadcast	Broadcast
Weed Emergence	Post	Pre	Pre	Pre

[a] UCP = upper coastal plain; LCP = lower coastal plain.
[b] Ars = Arsenal Ac; Gar 4 = Garlon 4; Chop = Chopper; Esc = Escort; Acc = Accord SP.

Measurement plots were internal to treatment plots. One row of buffer seedlings surrounded each measurement plot leaving 30 seedlings in 1999 and 36 seedlings in 2000 in each TX measurement plot. In MS and AL each measurement plot contained at least 50 measurement seedlings.

In 1999, all DAP treatments in TX were broadcast evenly by hand. In 2000, all DAP treatments in TX were applied with a cyclone seed sower. Plots were deliberately under-treated with the residual 15 percent applied by hand for a more even distribution.

Liquid treatments were applied with a "T" wand equipped with 4, 1101.5 TeeJet nozzles. Total application volume was 10 GPA.

Treatments were visually evaluated for percent control at 30, 60, 90 and 120 days after treatment (DAT). Control was expressed in 10 percent intervals with 0 = no control and 100 = total control. In 1999, individual species occupying at least 7 percent ground cover in all plots were evaluated separately. In 2000, diverse communities dominated plots. All herbaceous plants as a group were assessed for overall control.

For all sites, seedlings were assessed for survival (percent) and measured for height (cm) and ground line diameter (mm) prior to treatment and after one and two growing seasons. For analysis, height and ground line diameter data were converted to inches. Seedling volume was computed as volume index = ht*gld^2 and expressed in cubic inches.

The experimental design for all locations was a randomized complete block. The 1999 planting contained four blocks. All 2000 plantings had three blocks. An analysis of variance was conducted on survival, total height and volume index after one or two growing seasons. Duncan's New Multiple Range test P = 0.05) was used to separate treatment means.

Drought was severe during 1999 and 2000. All four tests were subject to uncommonly high temperatures and an extreme lack of moisture from July through October of 1999 and 2000.

RESULTS

1999 Post-Emergence Treatments

Liquid sprays and impregnated DAP provided similar control of purple cudweed (*Gamochaeta purpurea* (L.)Cabrera), a winter broadleaf, through 30 DAT (table 2). Small changes in control were observed 60 DAT. By 120 DAT, only 4 ounces of Oust impregnated on DAP provided similar control as liquid sprays. Impregnated DAP treatment provided an average of 14 percent less control of purple cudweed than liquid treatments 120 DAT. Liquid and impregnated treatments provided similar swamp sunflower (*Helianthus angustifolius* L.*)* control for 60 DAT; minor differences were detected 90 DAT. At 120 DAT, liquid spray exhibited more control than herbicide impregnated DAP treatments by an average of 24 percent. Differences in control of panicgrass (*Dichanthelium scoparium* (LAM.)Gould), *laxiflorum* (Lam.)Gould)*,* and *acuminatum* (Sw.)Gould & C.A. Clark*)* and all species were detected 30 DAT and differences among treatment control continued to diverge with time. By 120 DAT, liquid sprays of Velpar+Oust and 4 ounces of Oust provided 43 percent better panicgrass control than 2 ounces of Oust and herbicides impregnated on DAP. Averaged across all species, herbicide-impregnated DAP provided 38 percent less control than liquid herbicides. Perhaps weed control could be improved with two modifications. First, a pre-emergence application activates herbicide in the soil for control of germinating weed seeds. Second, impregnating 250 rather than 125 pounds of DAP doubles the number of soil contact points for better coverage.

Major differences were detected in year-one seedling survival and growth (table 3). Best survival was achieved with liquid sprays of Velpar+Oust or Oust (4 ounces). Treatments of Oust alone (2 ounces) or herbicide impregnated DAP provided intermediate survival. Minor differences in total height were detected but all spray and impregnated DAP treatments provided similar seedling volume. Lowest survival and volume were recorded for the untreated check and DAP only plots. Fertilization without weed control resulted in lower survival than doing nothing (untreated check).

After two growing seasons, mean liquid and mean impregnated treatments exhibited 71 percent and 64 percent survival, respectively. Also, survival across all treatments had decreased an average of 7 percent below year one levels. Furthermore, seedling heights were commonly below 5 feet, illustrating the impact of two consecutive drought years. Volume index was greatest for liquid and impregnated treatments containing 2 ounces of Oust, both with and without Velpar. A fertilizer response was not detected although plots treated with DAP supported 66 cubic inches and unfertilized plots 56 cubic inches of volume - a difference of 10 cubic inches. This growth difference is expected to increase over time. Weed control provided 2.5 times more volume and fertilizer+weed control produced 2.9 times more volume than checks.

2000 Pre-Emergence Treatments

At all three sites, competitor control was similar for several liquid and impregnated treatments (table 4). Control was best 30 DAT and declined disproportionately by 120 DAT. For example, in TX, MS and AL, mean herbicidal control 30 DAT and 120 DAT was 97 and 95, 97 and 83, and 86 and 70 percent, respectively. Values reflect different weed pressure that may be related to soil moisture. Of the three sites, the TX site was the best drained (table 1), had the slowest weed re-invasion, and therefore the best long-term control. In contrast, the AL site had the poorest drainage, fastest weed re-invasion, and therefore the worst long-term control.

Seedling survival and growth for several herbicide-impregnated-DAP treatments was similar to conventional liquid and two-pass herbicide-fertilizer treatments at all three sites (table 5). Growth trends are very preliminary and will be followed over time.

All Four Sites

When considering all four sites, (1) 2 ounces of Oust followed with DAP (conventional two-pass treatments), (2) two ounces of Oust impregnated on 125 pounds of DAP, (3) two ounces of Oust impregnated on 250 pounds of DAP or 4 ounces of Oust impregnated on 125 pounds of DAP provided 89, 79, 83 and 83 percent control of weeds 120 DAT, respectively. Increasing the DAP rate from 125 to 250 pounds doubled the number of soil contact points and increased control 4 percent. Holding the DAP rate constant and increasing the Oust rate from 2 to 4 ounces increased control 4 percent. However, neither increasing the rate of DAP nor the rate of Oust significantly increase control. When comparing the Velpar+Oust mixture, the traditional liquid spray provided 91 percent and impregnated DAP 88 percent weed control 120 DAT. Velpar alone on 125 pounds of DAP provided 79 percent weed control, a level significantly less and 12 percent below the conventional liquid Velpar+Oust treatment. Increasing the number of contact points by impregnating 250 pounds of DAP increased weed control by 1 percent. The difference among the traditional liquid spray and Velpar impregnated on 250 pounds of DAP was 11 percent and not significant. Post-emergence liquid sprays of Velpar+Oust provided 85 percent weed control in contrast to 45 percent weed control for Velpar+Oust impregnated DAP. When the same treatments were applied pre-emergence, the conventional Velpar+Oust spray provided 90 and the impregnated DAP 89 percent control, a loss of 1 percent. Clean, well prepared sites promote product-soil contact and seed-originating competitors. For best results, managers contemplating this technology should commit to clean, well-prepared sites and early applications of impregnated DAP as a joint package.

CONCLUSIONS

On clean, well-prepared sites in TX, MS, and Al, pre-emergence applications of Oust, Velpar+Oust impregnated DAP, and Velpar impregnated on 250 pounds of DAP provided comparable herbaceous weed control 120 DAT as conventional liquid treatments of Oust or Velpar+Oust. Growth trends are very preliminary, with first- and second-year seedling survival and growth similar for liquid and herbicide-impregnated-DAP treatments and better than for checks. Managers interested in weeding-and-feeding seedlings at planting should consider levels of post-harvest biomass, intensive site preparation, and pre-emergence, herbicide-impregnated DAP treatments all part of an integrated package. Drought probably influenced study results.

Table 2—Control (percent) of unwanted herbaceous competitors with a March 22, 1999, early post-emergence application over the top of newly planted loblolly pine seedlings in East TX (Angelina County)

Treatments	Rate and formulation[a]		Days after treatment[b] 30	60	90	120
purple cudweed (*Gamochaeta purpurea* (L.)Cabrera)						
Velpar+Oust	1qt+2oz	S	100a	100a	100a	100a
V+O+DAP	1qt+2oz+125 lb	G	100a	95a	83ab	75b
Oust	4oz	S	100a	98a	98a	98a
Oust+DAP	4oz+125 lb	G	98a	97a	95a	95a
Oust	2oz	S	100a	97a	92ab	87ab
Oust+DAP	2oz+125 lb	G	90a	85b	75b	72b
DAP	125 lb	G	0c	0c	0c	0c
swamp sunflower (*Helianthus angustifolius* L.)						
Velpar+Oust	1qt+2oz	S	100a	100a	99a	99a
V+O+DAP	1qt+2oz+125 lb	G	93a	85a	83ab	63b
Oust	4oz	S	100a	100a	100a	99a
Oust+DAP	4oz+125 lb	G	99a	97a	85ab	85b
Oust	2oz	S	99a	98a	91a	91a
Oust+DAP	2oz+125 lb	G	83a	81a	70b	70b
DAP	125 lb	G	0b	0b	0c	0c
panicgrasses (*Dichanthelium* scoparium, *laxiflorum, acuminatum)*						
Velpar+Oust	1qt+2oz	S	100a	95a	95a	88a
V+O+DAP	1qt+2oz+125 lb	G	92b	85b	81b	38b
Oust	4oz	S	99a	96a	96a	92a
Oust+DAP	4oz+125 lb	G	92b	83bc	80bc	43b
Oust	2oz	S	98a	90a	83ab	60b
Oust+DAP	2oz+125 lb	G	85c	75c	73c	38b
DAP	125 lb	G	0d	0d	0d	0c
all species						
Velpar+Oust	1qt+2oz	S	95a	93a	89a	86a
V+O+DAP	1qt+2oz+125 lb	G	71bc	68b	46cd	45cd
Oust	4oz	S	86ab	80a	78ab	76b
Oust+DAP	4oz+125 lb	G	64c	60bc	38cd	36de
Oust	2oz	S	76bc	81a	60bc	55bc
Oust+DAP	2oz+125 lb	G	61c	50c	25d	21e
DAP	125 lb	G	0d	0d	0e	0f

[a] A single application of DAP. S = Liquid spray. G = Granule.

[b] Treatment means within a column sharing the same letter are not significantly different (Duncan's New Multiple Range test, P = 0.05 level).

Table 3—Treatments were applied near Beulah (Angelina County), TX on March 22, 1999 and loblolly pine seedling survival (S1, S2, pct), total height (H1, H2, inches) and total volume (V1, V2, in^3) determined after one and two growing seasons

Treatments[a]	Rate and formulation[b]		S1	H1	V1	S2	H2	V2
Velpar+Oust	1qt+2oz	S	87a	19.8ab	3.9a	79a	55.0ab	70.6a
V+O on DAP	1qt+2oz on 125 lb	G	73b	20.6a	3.8a	69abc	57.0a	76.0a
Oust	2oz	S	74b	18.0bc	3.7a	65bc	52.5ab	60.0ab
Oust on DAP	2oz on 125 lb	G	72b	21.5a	4.4a	65bc	55.9a	68.1ab
Oust	4oz	S	78ab	16.4c	3.1a	69ab	46.3d	40.1cd
Oust on DAP	4oz on 125 lb	G	68b	18.4bc	3.2a	58c	51.2bc	54.3bc
DAP	125 lb	G	28d	17.2c	1.6b	24e	47.2cd	25.8de
Check	None	-	40c	19.6ab	1.5b	38d	43.1d	22.6e

[a] Treatment means within a column sharing the same letter are not significantly different (Duncan's New Multiple Range test, P = 0.05 level).

[b] A single application of DAP. S = Liquid spray. G = Granule.

Table 4—Control (pct) of herbaceous weeds 30-120 days after pre-emergence (99 percent bare ground) treatment (DAT)

Treatment[a]	Rate and formulation[b]		30&60 DAT	90 DAT	120 DAT
Diboll, TX — Treated 9-Mar-00					
Oust	2oz	S	99a	98a	98a
Oust Then DAP	2oz & 125 lb	S;G	98a	98a	98a
Oust on DAP	2oz on 125 lb	G	89c	89a	91ab
Oust on DAP	2oz on 250 lb	G	99a	98a	98a
Oust on DAP	4oz on 125 lb	G	99a	98a	98a
Velpar+Oust	1qt+2oz	S	99a	98a	98a
V+O on DAP	1qt+2oz on 125 lb	G	98ab	98a	98a
Velpar on DAP	1qt on 125 lb	G	92bc	83ab	83b
Check	none		40d	40c	37c
DAP	125 lb	G	50d	45c	40d
Picayune, MS — Treated 16-Mar-00					
Velpar+Oust	1qt+2oz	S	99a	99a	97a
V+O on DAP	1qt+2oz+125 lb	G	99a	99a	85ab
Velpar on DAP	1qt+125 lb	G	96a	96a	67b
Velpar on DAP	1qt+250 lb	G	97a	68a	90ab
Oust	2oz	S	98a	59b[c]	38c[c]
Oust Then DAP	2oz & 125 lb	S;G	97a	97a	88ab
Oust Then DAP	2oz & 250 lb	S;G	97a	98a	85ab
Oust on DAP	2oz+125 lb	G	96a	96a	75ab
Oust on DAP	2oz+250 lb	G	97a	98a	85ab
Oust on DAP	4oz+125 lb	G	98a	98a	75ab
Check	None		45c	45b	5d
DAP	125 lb	G	57b	50b	7d
Whitfield,AL — Treated 3-April-00					
Velpar+Oust	1qt+2oz	S	93a	83a	75ab
V+O on DAP	1qt+2oz+125 lb	G	93a	81ab	77a
Velpar on DAP	1qt+125 lb	G	79c	74ab	70abc
Velpar on DAP	1qt+250 lb	G	81bc	74ab	70abc
Oust	2oz	S	90ab	83a	66bc
Oust Then DAP	2oz & 125 lb	S;G	90ab	83a	75ab
Oust Then DAP	2oz & 250 lb	S;G	76c	72b	66bc
Oust on DAP	2oz+125 lb	G	79c	72b	62c
Oust on DAP	2oz+250 lb	G	85abc	74ab	65bc
Oust on DAP	4oz+125 lb	G	90ab	78ab	73ab
Check	none		42e	39d	37d
DAP	125 lb	G	58d	49c	45d

[a] A single application of DAP. S = Liquid spray. G = Granule.
[b] Treatment means within a column sharing the same letter are not significantly different (Duncan's New Multiple Range test, P = 0.05 level).
[c] Heavy rainfall within one-hour of application may have influenced this value.

Table 5—Loblolly pine seedling survival (S1, pct) and growth (Height = H1, inches), Volume Index = V1, cubic inches) after one growing season

Treatment[a]	Rate and formulation[b]		S1	H1	V1
Diboll, TX					
Oust	2oz	S	92ab	22.4abc	7.7bc
Oust then DAP	2oz & 125 lb	S;G	94a	24.3a	9.4ab
Oust on DAP	2oz on 125 lb	G	85abc	21.2bc	8.2b
Oust on DAP	4oz on 125 lb	G	88abc	23.7ab	10.9a
Oust on DAP	2oz on 250 lb	G	82bcd	20.7c	7.9bc
Velpar+Oust	1qt+2oz	S	92ab	19.9c	7.4bc
V+O on DAP	1qt+2oz on 125 lb	G	83bc	19.6c	7.3bc
V on DAP	1qt & 125 lb	G	79cd	21.7abc	5.6cd
DAP	125 lb	G	46e	17.0d	2.1e
Check	None		73d	20.2c	3.6de
Whitfield, AL					
Oust	2oz	S	59ab	15.0e	2.8cd
Oust then DAP	2oz & 125 lb	S;G	69a	18.4ab	3.8ab
Oust then DAP	2oz & 250 lb	S;G	67ab	19.4a	4.4a
Oust on DAP	2oz on 125 lb	G	66ab	16.9bcd	2.4cd
Oust on DAP	4oz on 125 lb	G	57b	16.8cd	3.2bc
Oust on DAP	2oz on 250 lb	G	67ab	19.6a	4.4a
Velpar+Oust	1qt+2oz	S	57b	18.8a	4.5a
V+O on DAP	1qt+2oz on 125 lb	G	58ab	17.0bcd	3.2bc
V on DAP	1qt on 125 lb	G	63ab	16.7cd	2.7cd
V on DAP	1qt on 250 lb	G	68ab	18.5ab	3.3bc
DAP	125 lb	G	67ab	18.3abc	3.0bc
Check	None		65ab	16.6d	2.0d
Picayune, MS					
Oust	2oz	S	100a	21.8e	10.2e
Oust then DAP	2oz & 125 lb	S;G	100a	31.1bc	32.9b
Oust then DAP	2oz & 250 lb	S;G	99a	32.2b	39.8a
Oust on DAP	2oz on 125 lb	G	100a	30.2c	33.8b
Oust on DAP	4oz on 125 lb	G	100a	31.8b	28.5c
Oust on DAP	4oz on 250 lb	G	100a	30.3c	29.2c
Velpar+Oust	1qt+2oz	S	100a	31.5c	24.6d
V+O on DAP	1qt+2oz on 125 lb	G	100a	33.5a	33.2b
V on DAP	1qt on 125 lb	G	100a	27.5d	21.6d
V on DAP	1qt on 250 lb	G	100a	32.2b	38.1a
DAP	125 lb	G	100a	21.1ef	8.6e
Check	None		98b	20.2f	5.1f

[a] Treatment means within a column sharing the same letter are not significantly different (Duncan's New Multiple Range test, P = 0.05 level).
[b] A single application of DAP. S = Liquid spray. G = Granule.

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RESPONSE OF 1- TO 4-YEAR-OLD UPLAND HARDWOOD STANDS TO STOCKING AND SITE MANIPULATIONS

Jamie L. Schuler and Daniel J. Robison[1]

Abstract—The growth and development of very young natural even-aged hardwood stands is not well understood. The relative importance of biotic and abiotic constraints such as overstocking, herbaceous competition, tree nutrition, and pest impacts have not been widely studied in these types of stands. Earlier work has demonstrated significant tree growth response (2- to 20-fold) to release from these constraints. This paper will report on the continued measurement of these plots through year 4. Also, a new series of plots in 1 and 3 year old stands have been followed for 1.5 years. Treatments imposed include thinning, herbaceous competition control, fertilization, and combinations of these treatments. These experiments are beginning to show the potential of very early stand interventions to shorten rotation ages in upland hardwoods. These efforts are part of a broader set of initiatives across the South by the NC State Hardwood Research Cooperative to explore early interventions for stocking and competition control as a silvicultural option in managing hardwoods.

INTRODUCTION

The growth and development of very young natural even-aged hardwood stands is not well understood. While a general understanding of regeneration and self-thinning processes is accepted, the relative importance of biological constraints such as tree stocking, herbaceous competition, tree nutrition, and pest impacts have not been widely studied in these types of stands. Earlier work has demonstrated significant tree growth response (2- to 20-fold) to release from these constraints at ages 1 and 2 (Romagosa 1999, Romagosa and Robison 1999).

Southern hardwoods are often managed under an even-aged silvicultural system, with clearcutting prescribed as the regeneration method. Clearcutting commonly regenerates 25,000 - 100,000 stems/hectare. Given that current rotations for pulpwood and sawtimber at completion contain about 1000 and 250 harvestable stems/hectare, respectively, it seems apparent that 25,000 or more stems/hectare at establishment is well overstocked. This overstocking is often cited as a major factor constraining growth in forest stands. The numerous seedlings and sprouts from undesirable species retard the growth of more desirable species (Kays and others 1988).

A large number of thinning studies in young stands between 9 and 20 years of age were published, most with beneficial results (e.g. Heitzman and Nyland 1991, Johnson and others 1997, Pham 1985, Smith and Lamson 1983). However, the degree to which density affects growth at younger ages has not been quantified. Similarly, weed competition (herbaceous and woody) is known to seriously impede growth. This has been documented in plantations and natural stands for hardwood and coniferous species (e.g. Kolb and others 1989, Miller and others 1995, Nelson 1985, Romagosa and Robison 1999), but not evaluated fully within the control of other constraints.

Other biotic factors known to depress growth and prolong rotations include deer browse, and insect and fungal attack (Galford and others 1991, Korstian 1927, Marquis 1981). Experiments with deer exclosures through fencing and chemical repellants have demonstrated dramatic differences in height growth and species composition (Brenneman 1983, Marquis 1981). Stanosz (1994) used systemic pesticides to control insects and fungi on 1-year-old sugar maple (*Acer saccharum*) seedlings and had positive effects.

Tree nutrition has received much research attention, demonstrating the exceptional gains in productivity possible with fertilization (Allen and others 1990). Little nutrition research has focused on young hardwood stands outside of plantation culture. The few published studies show mixed results. Graney and Rogerson (1985), working with shelterwood regeneration, reported no effect of nitrogen fertilization on 5-year heights for oak seedlings, but increased white ash (*Fraxinus americana*) and cherry (*Prunus serotina*) 5-year heights. They cited extreme herbaceous competition exacerbated by fertilization as the cause. By contrast, significant responses to nitrogen and phosphorus were shown for 7 and 12 year old black cherry (*Prunus serotina*) stands in Pennsylvania (Auchmoody 1985) and 7 year old mixed hardwoods in North Carolina (Newton and others, this issue).

In the current study we report on the results of 2 studies. Both focused on factors constraining tree growth in very young (1 to 4 years old) naturally regenerated hardwood stands. In Experiment One, we report the 4-year effects of ameliorating weed competition and pest impacts for 2 years. In Experiment Two, we quantified the effects of overstocking, weed competition, and fertilization on very young upland hardwood stands.

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METHODS

Experiment One

Experiment One was installed on three clearcut sites in the North Carolina Piedmont. The sites are located on 2 of the NC State University owned forests, the Schenck Memorial Forest (Wake County) and the Hill Forest (Durham County). Each site was salvage clearcut during the winter of 1996/97, prompted by hurricane Fran. The three sites have previously held stands of mixed pine-hardwoods, natural mixed hardwoods, and loblolly pine plantation. All sites have south-facing aspects and Cecil sandy loam soils on 2-10 percent slopes.

Four treatments were applied to 10 square meter square plots with 1 meter borders in a randomized complete block design with 4 replications. The treatments, applied during the growing seasons of 1997 and 1998 (years 1 and 2 after clearcutting), consisted of:

(1) Pesticide- an insecticide, fungicide, and mammal repellant sprayed periodically over the vegetation
(2) Weeded-hand shearing of all non-hardwood vegetation
(3) Full- pesticide and weeded treatments
(4) Untreated control

Due to space restrictions, site 1 had all four treatment plots, site 2 only treatments 3 and 4, and site 3 had treatments 1, 3, and 4. More detailed site and experimental design descriptions are contained in Romagosa and Robison (1999). The data reported include the 2 years when treatments were applied (age 1-2) and the 2 years after treatments were discontinued (age 3-4).

Experiment Two

Treatments were established on 2 upland North Carolina Piedmont sites. The Hill site (Hill Forest, Durham County), formerly a 2 hectare loblolly pine (*Pinus taeda*) stand with a small component of hardwoods, was clearcut logged in 1999. The Duke site (Duke Forest, Orange County), formerly a 5 hectare mature mixed oak (*Quercus sp.*) stand, was salvage clearcut in 1996/97 in response to damage from hurricane Fran. The Hill site has Cecil soils with undulating topography. The Duke site has Appling silt loam soils with a north-facing aspect on 2-10 percent slopes.

Ten square meter circular plots with 1 meter borders were randomly located, insofar as each plot contained at least 2 yellow-poplar (*Liriodendron tulipifera*) and 2 oak trees. Each site contained a total of 8 treatments replicated in 4 blocks. The treatments were begun in July 1999 and continue to the present. The treatments were installed in a 2x2x2 factorial design with the main factors being:

(1) Weeded vs. unweeded- hand removal of all non-arborescent vegetation
(2) Fertilized vs. unfertilized- 90 kilograms/hectare of nitrogen and 100 kilograms/hectare of phosphorus applied as diammonium phosphate
(3) Thinned vs. unthinned-stem density reduced to 4 stems/plot, consisting of 2 yellow-poplar and 2 oak trees

The data reported for Experiment Two focus on the 5 most dominant yellow-poplar in each of the unthinned plots and the 2 yellow-poplars in each thinned plot. Therefore, the data represented a total of 8 stems on thinned and 20 on unthinned plots. This was done to reduce the error associated with different species composition among treatments and blocks. Yellow-poplar was selected for comparison because it represents an important timber species in the region, it existed in all plots, and as a fast-growing shade intolerant species it provides a rapid measure of treatment effects.

Table 1—Density and growth response for 3 (1997) and 4 (1998)-year-old hardwood and pine seedlings in Experiment One (see text for description) averaged across three upland North Carolina Piedmont sites. Pines had been removed from the weeded and full study plots during years 1 and 2

		Stem Count (No./10 m^2)		Basal Diameter (mm)		Total Height (cm)	
Treatment	Species	1999	2000	1999	2000	1999	2000
Control	hardwood	163	163	8.7	11.8	61	107
	Pine	146	193	13.2**	20.0**	78**	131**
Pesticide	hardwood	60	60	8.7	12.7	64	113
	pine	178	196	11.8**	19.7**	76*	137**
Weeded	hardwood	163	153	14.0	17.2	85	116
	pine	0	0	-	-	-	-
Full	hardwood	353	376	16.3	18.9	110	145**
	pine	0	7	-	1.4	-	14

Significant differences between hardwood and pine seedlings within each treatment/year pair are designated by * for alpha = 0.1 and ** for alpha = 0.05. Stem count data were not analyzed for differences. Pesticide treated plots received a combination of pesticides only, weeded plots had all non-hardwood vegetation removed, and the full treatment was pesticide + weeded. Treatments were applied during years 1 and 2, then discontinued.

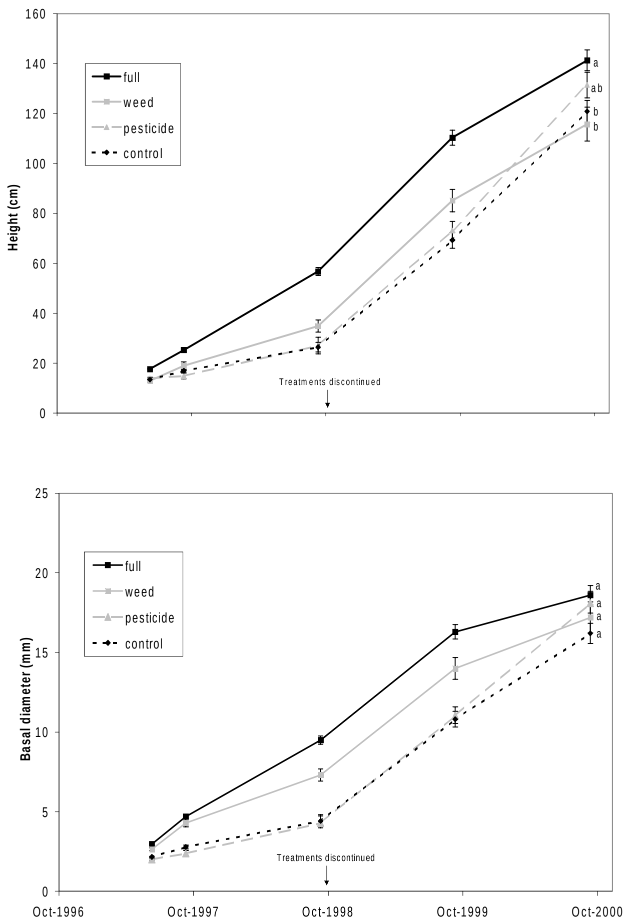

Figure 1—Mean height (top) and basal diameter (bottom) (3 sites, 8-12 plots per treatment) of natural regeneration following winter 1996/97 clearcutting on NC upland Piedmont sites. Different letters indicate statistical differences at alpha = 0.05 using ANOVA protected LSD means separation procedure. The arrow indicates the time when treatments were discounted.

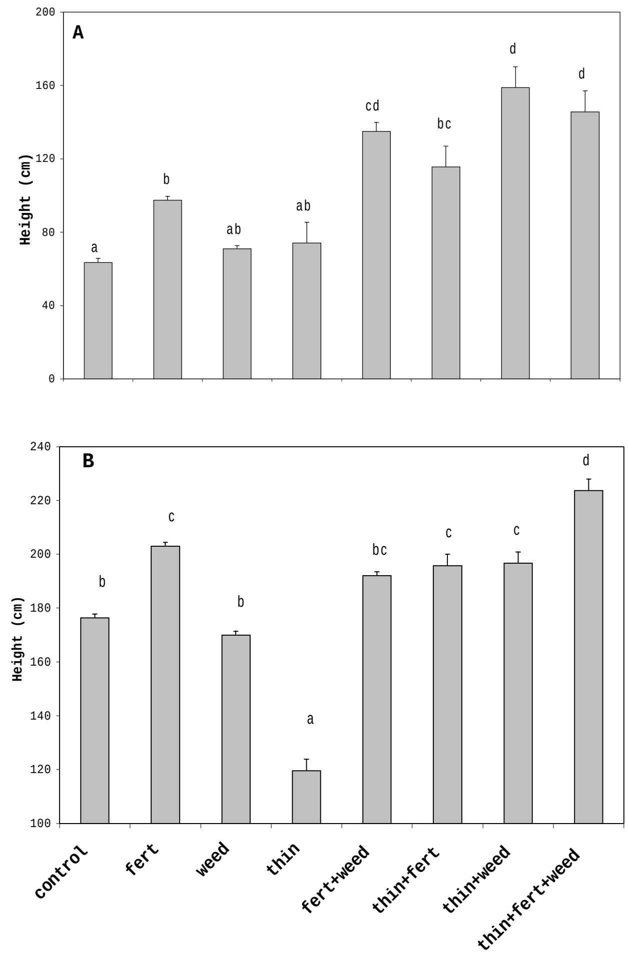

Figure 2—Mean (+/-SE) height of dominant yellow-poplar at age 2 (1.5 years of treatment) at the Hill Forest (a, top), and at age 4 (1.5 years of treatment) at the Duke forest (b, bottom). Different letters indicate statistical differences at alpha = 0.05 using ANOVA protected LSD means separation procedure.

RESULTS AND DISCUSSION

Experiment One

Romagosa and Robison (1999) reported substantial and significant gains attributed to weeding and full treatments for the first 2 years of treatment. After 4 years of growth (treatments were applied during the initial 2 years) the full treatment still has greater cumulative heights and diameters, but significant differences ($P < 0.05$) only occurred for height growth (figure 1). By year 4, the pesticide and control treatments marginally surpassed the weeded treatments in height and diameter growth. These trends suggest convergence among treatments.

However, the application of the treatments inadvertently complicated the study. For the weeded and full treatments, all non-hardwood vegetation, including pine trees, were periodically sheared for 2 years. As a result, we are seeing the effects of loblolly pine on the control and pesticide treated plots (where they were not removed) beginning to out compete the hardwood seedlings on these shallow Cecil soils with southerly-facing slopes. On the control and pesticide treated plots at the end of year 4, loblolly pine accounted for roughly 50 and 75 percent of the stem count, respectively. By the end of the 4th growing season (2000), the loblolly pine component was accumulating more diameter and height growth than the hardwoods (table 1). By examining the curves in figure 1, and either mentally factoring pines into the full and weeded plots, or factoring them out of the pesticide and control plots, the trends do suggest a continuing positive effect of the treatments.

Experiment Two

Initial height measurements were significantly different ($P<0.05$) among treatments for both sites. Therefore, the 2000 cumulative height data were adjusted using initial height as a covariate.

Fertilization significantly improved yellow-poplar height growth (+ 54 percent) after 1.5 years on the 2-year-old Hill site (figure 2a). The combination of fertilization + weeding showed a positive interaction ($P = 0.0791$), as did thinning

+ weeding (P = 0.0587). Results suggest that weeds compete more strongly than seedlings with the dominant yellow-poplar trees. However, when both competitors were removed large gains in height growth were observed.

Fertilization significantly enhanced yellow-poplar height growth (+15 percent) after 1.5 years, on the 4-year-old Duke site (figure 2b). Again, weeding and thinning treatments had no measurable positive effect on dominant yellow-poplar height growth. Fertilization out performed all other treatments except for the combined effects of thinning + fertilization + weeding. We surmise that the availability of nutrients became limiting on this site as tree seedlings and other vegetation competed for the similar resources. Even when thinning, weeding, and fertilization treatments are combined, the yellow-poplar trees only grew 10 percent more than for fertilization alone.

CONCLUSIONS

The objectives of this work were to determine if early stand interventions could be used to identify factors that constrain productivity on upland Piedmont sites. Both experiments demonstrate the potential of early silvicultural treatments to accelerate growth and possibly reduce rotation lengths.

The 4-year results (through age 4) from Experiment One suggest that early gains are sustainable even after treatments are discontinued. Full treatments have maintained a growth advantage over all other treatments.

In Experiment Two, both the 1- and 3-year-old stands responded well to fertilization after 1.5 years. Thinning and weeding treatments suggest that at very early ages weed competition is more severe than competition from other seedlings, at least for dominant yellow-poplar seedlings. Thinning and weeding showed synergistic effects when combined together.

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Mark Romagosa initiated Experiment One and graciously provided the first 2 years of data. The authors thank Jim Bridges, Judson Edeburn, David Gadd, Robert Jetton, Leslie Newton, and David Nishida for their assistance with these studies, and the NC State University Hardwood Research Cooperative members for supporting this work.

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ACCELERATING PLANTED GREEN ASH ESTABLISHMENT ON AN ABANDONED SOYBEAN FIELD

John W. Groninger and Didier A. Babassana[1]

Abstract–Planted green ash seedlings exhibit high survival rates on most bottomland sites that have recently come out of row crop production, making this species a popular choice for afforestation. Sub-optimal growth of planted hardwood tree species, including green ash, often delays the realization of many of the economic and environmental benefits that are used to justify the expense of tree planting and land use conversion. This study evaluates the impacts of silvicultural treatments, including pre-planting discing, and two herbicide treatments (sulfometuron and glyphosate) on early stand development in a green ash planting on a former soybean field in southern Illinois. After two growing seasons, both herbicide treatments increased green ash height growth while tillage produced no response. Sulfometuron increased total cover and percent grass cover relative to glyphosate and unherbicided treatments, largely by stimulating the growth of broomsedge (Andropogon virginicus). Glyphosate doubled broadleaf cover relative to the sulfometuron and no herbicide treatments.

INTRODUCTION

Formerly-forested bottomland sites offer excellent opportunities for afforestation in the lower Midwest and Mid-south. Typicaly, these sites were cleared of forest cover during the soybean boom of the 1960's and 70's but are now considered marginal for row crop agriculture. More recently, private and government programs are resulting in restoration of native hardwood cover to many of these sites (Stanturf and others 2000).

While survival and growth of planted trees is usually adequate to satisfy afforestation guidelines, the combination of planted trees and volunteer vegetation have failed to produce forest cover in some areas. Establishment failures in similar settings have been attributed to poor matching of species and site (Hodges 1997). Sometimes, these conditions are an unintended consequence of long-term row crop agriculture and may ultimately limit the number of desirable species that are suitable for the site. Green ash (Fraxinus pennsylvanica Marsh.) is one species with demonstrated utility in formerly farmed bottomland sites and was therefore selected for use in this study (Groninger and others 2000).

Competition from herbaceous vegetation also appears to hamper the establishment of canopy cover on similar sites. Funds are generally available through cost share programs for vegetation control treatments, including tillage and herbicides. However, their use is limited because several local land managers question the value of these treatments. The objectives of this study were to evaluate the efficacy of tillage and herbicide treatments, alone and in combination on the establishment of planted green ash. Further, volunteer herbaceous vegetation response to these treatments were evaluated.

METHODS

This study was conducted on a poorly drained site in Saline County, Illinois. Soils were classified as a Bonnie silt-loam (Fine-silty, mixed, acid, mesic, Typic Fluvaquents). The site had been cleared of forest cover ca. 1967 and cropped periodically thereafter in soybeans. Corn was planted in 1997 and the site left fallow in 1998. In Fall 1998, the site was mowed and enrolled in the Wetlands Reserve Program.

The tilled treatments consisted of a) three passes with a tandem disk drawn by a 40 hp farm tractor and b) an untilled control. Tillage was carried out on May 8, 1999, the earliest date soil moisture conditions permitted use of this equipment. Herbicide treatments consisted of a) sulfometuron methyl, b) glyphosate, and c) an untreated control.

Green ash seedlings (1-0) of unknown origin were obtained from the Illinois State Tree Nursery. Seedlings were machine planted on May 4 with follow-up hand planting to replace mis-planted individuals on May 28. Immediately following replacement planting, herbicide treatments were initiated. Sulfometuron was applied over the top using an ATV mounted with a 10 foot boom as 2 oz Oust/ac. in a water carrier. At that time, budbreak had occurred in some seedlings. The glyphosate treatment was applied on July 8 as 1.5 percent RoundupPro solution using a water carrier. The glyphosate treatment was applied to a 4.5 foot diameter circle around each seedling. During the glyphosate application, seedlings were shielded with a 4" diameter stovepipe to prevent herbicide contact with foliage.

Seedling survival and height were measured during the winter following the first and second growing season. Deer

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Table 1—Mean end of growing season height for planted green ash in response to competition control treatments. Means within a column followed by the same letter are not significantly different (á < 0.05)

Treatment	Year 1	Year 2
	----------Height(inches) ---------	
No herbicide	14a	26a
Glyphosate	20b	39b
Sulfometuron	18b	40b

Table 2—Predominant volunteer vegetation across competition control treatments during the second growing season

Species	Cover (percent)
Crabgrass (Digitaria sanguinalis)	22
Broomsedge(Andropogon virginicus)	13
Barnyard grass(Echinochloa crusgalli)	7
Goldenrod (Solidago spp.)	4
Horseweed(Conyza canadensis)	3
Trumpet creeper(Campsis radicans)	2
Yellow nutsedge(Cyperus esculentus)	2

Table 3—Second-year volunteer vegetation response to competition control treatments. Means within a column followed by the same letter are not significantly different (< 0.05)

	Broadleaves	Grasses	Total cover
	--------------percent--------------		
No herbicide	11 a	31 a	42 a
Glyphosate	24 b	33 a	57 a
Sulfometuron	11 a	66 b	77 b

and rodent damage were assessed immediately prior to bud break preceding the second growing season. Identity and percent cover of each herbaceous species were determined during early August within a 0.5 m^2 area surrounding each planted seedling.

The study employed a randomized split plot design where main plots consisted of tillage treatments and split plots consisted of the herbicide treatments. Each experimental unit consisted of 20 green ash seedlings. The study was replicated four times with blocks intended to account for soil moisture conditions. Significant differences between treatments were identified using Duncan's New Multiple Range Test (< 0.05). Tree height and cover data were

Table 4—Second-year broomsedge and horseweed cover response to competition control treatments. Means within herbicide and tillage within a column followed by the same letter are not significantly different (< 0.05)

Treatment		Broomsedge	Horseweed
		----Cover (percent)----	
Herbicide	No herbicide	8 a	3 a
	Glyphosate	5 a	11 a
	Sulfometuron	27 b	7 a
Tillage	No tillage	22 b	3 b
	Tillage	5 a	11 a

transformed using logarithmic and arc sine transformations, respectively.

RESULTS AND DISCUSSION

Green ash survival at the end of two growing seasons exceeded 95 percent in all treatments and was not considered in further analyses.

Tree growth

Green ash height was greater in response to herbicide treatments following both the first and second growing seasons (table 1). Herbicide treatments did not differ from one another in terms of growth response despite the fact that the pre-emergence sulfometuron application resulted in a longer period of nearly total weed control than the post-emergence glyphosate treatment.

Seedlings showed evidence of foliar damage, including chlorosis and small leaf size, in response to sulfometuron application (Babassana 2000). Ezell and Catchot (1997) and Horsley and others (1992) reported similar damage in response to post-foliation application of sulfometuron at similar rates. Although herbicide damage did not impact survival rate, resources that might have otherwise increased height growth were needed to overcome herbicide-induced injury. An unusually dry late spring may have also played a role in eliminating competition control gains associated with the earlier weed control treatment.

The tillage treatment did not effect seedling growth, consistent with the findings of Kennedy (1985). Successful tillage operations appear to require multiple treatments at least through the first growing season (Devine and others 2000).

Deer browsing between the first and second growing seasons was minimal (< 3 percent across treatments) which may reflect a particularly mild winter or the relative unpalatability of green ash seedlings (Rayburn and Barkalow 1973). Deer browse will be assessed immeidately prior to the third growing season, following a particularly long and cold winter.

Volunteer Vegetation

Volunteer community composition during the second growing season was typical of an abandoned bottomland field in this region (Bazzaz 1968) dominated by native and exotic grass and forb species (table 2). Volunteer community composition differed in response to herbicide treatments (table 3). Glyphosate more than doubled percent cover of broadleaf weeds over the other herbicide treatments. Sulfometuron resulted in 100 percent greater grass cover relative to glyphosate and the control. Overall, sulfometuron resulted in the highest average percent vegetation cover, driven largely by increased broomsedge cover (table 4). Tillage generally did not impact cover of dominant weed species. Exceptions were broomsedge which was decreased by tillage and horseweed which was increased by tillage.

Increased broomsedge dominance in response to weed control has been widely observed (Miller and others 1995). The antagonistic effects of broomsedge on first-year growth of trees is well-documented (Morris and others 1989; Zutter and others 1999). In the present study, broomsedge is becoming dominant somewhat later in stand development and may therefore impact tree growth differently. In the present study, the two herbicide treatments resulted in differing community composition but result in virtually identical tree growth. In this setting, the apparently increasing importance of broomsedge should provide some information regarding the role of post-establishment community composition on green ash growth in the coming years.

CONCLUSIONS

After two growing seasons, herbicides, but not tillage, improve green ash height growth. The amount and composition of volunteer vegetation differed among herbicide treatments providing land managers with the flexibility to establish a range of herbaceous community types while simultaneously accelerating tree canopy closure. Further monitoring will be required to determine the effects of these treatments on long-term vegetation development.

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HERBACEOUS WEED CONTROL IMPROVES SURVIVAL OF PLANTED SHUMARD OAK SEEDLINGS

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Abstract—Shumard oak seedlings were planted on a cutoversite in the Mississippi River floodplain, which had received both chemical and mechanical site preparation treatments. Soil at the site was a commerce silt loam and the elevation was such that the area does not flood. Planting stock was 1-0, bareroot seedlings. A total of seven active herbicide treatments were applied at a preemergent timing over the top of the planted seedlings prior to the onset of the 1998 growing season. In addition, an untreated check was established and all treatments were replicated three times. Each plot consisted of 200 linear feet of planted row with 20 seedlings. Seedlings were tagged and flagged for measurement purposes. Competition control was evaluated at 30, 60, 90 and 150 days after treatment. At each evaluation timing, the seedlings were evaluated for any symptoms of herbicide damage. In November of 1998 and 1999, seedling survival was recorded. Overall, herbaceous competition control significantly increased seedling survival. Differences exist among treatments and between year of observation. Without herbaceous competition control, seedling survival and plantation establishment may be questionable in areas of severe weed pressure.

INTRODUCTION

Thousands of acres are being planted with hardwood species in the South each year. These hardwood seedlings cost more than pine seedlings and planting costs are typically greater for hardwoods. Higher planting costs combined with longer rotation lengths combine to create a scenario in which high survival rates are essential to improve the cost-efficiency of the planting operation.

Unfortunately, survival in many of these planting efforts has been less than desirable (James 2000). The lack of desirable survival rates has been especially true of the oak species planted. In oak planting, initial survival is principally dependent upon three factors: seedling quality, planting quality, and competition control (or the lack thereof). For optimal results in oak plantings, larger, rigorous seedlings must be handled and planted properly, and the herbaceous competition should be controlled for at least a portion of the first growing season (Ezell 2000). Depending on the site, species planted, and growing conditions during the first year following planting, the control of competing vegetation con improve oak seedling survival from an appreciable amount (20 percent) to what could be considered a critical amount (80 percent or greater) (Ezell and Catchot 1997, Ezell 2000).

MATERIALS AND METHODS

Study Site

The study was installed on land owned by Anderson-Tully Company in Bolivar County, MS. The site is in the Mississippi River floodplain but does not flood, and the soil series across the area is a commerce silt loam. The stand had been harvested in 1997 with a complete removal of all merchantable stems, and an aerial application of herbicide was applied late in the growing season of 1997 to control residual undesirable woody vegetation. The area was hand planted with 1-0, bareroot Shumard oak seedlings in January 1998.

Treatments

On March 18, 1998, a total of seven herbicide treatments were applied to the planted area. These applications are considered preemergent in reference to the fact that the oak seedlings had not visibly broken dormancy (no bad swelling, bad break, etc.). A complete list of treatments is found in table 1.

All treatments were applied over-the-tops of the planted oak seedlings as a banded treatment. Each treatment band was a 6-foot wide spray swath, which had the planted oaks as the center of the band. All treatments were replicated three times in a randomized complete black design. Each treatment plot was a linear area 200 feet long, which contained a minimum of 16 oak seedlings. All treatments were applied using a CO_2 powered backpack sprayer with a TK 2.5 Floodjet nozzle on a hand-held wand, which delivered a total spray volume of 20 gallons per acre at a pressure setting of 30 psi.

Seedling Measurements

Each oak seedling in the treatment plots were identified by placing a pin flag carrying a permanent number aluminum tag approximately two inches from the base of the seedling. This permanent number identified the seedling to facilitate consistency of data recording and comparison of data from different evaluation times. Initial height (centimeters) and groundline diameter (millimeter) were recorded for each seedling.

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Table 1—List of treatments applied in Shumard oak study

Treatment No.	Herbicide (rate per acre)[a]
1	2 oz Oust
2	64 oz Goal 2XL
3	5.6 oz Scepter 70DG
4	96 oz Goal 2XL
5	64 oz Goal + 5.6 oz Scepter 70DG
6	2.8 oz Pursuit DG
7	2.8 oz Pursuit DG + 5.6 oz Scepter 70DG
8	Untreated check

[a] All rates are expressed in amount of product per acre

Table 2—Average survival of Shumard oak seedlings in treatment plots

Survival Treatment No.	1998	1999
	Percent	
1	69.4b[a]	63.9b
2	80.6a	80.6a
3	63.9b	70.8b
4	86.1a	66.7b
5	91.7a	80.6a
6	66.7b	58.3bc
7	52.8c	47.2c
8	77.8ab	44.4c

[a] Values followed by the same letter do not differ at P=0.05

Plot Evaluation

All treatment plots were evaluated at 30, 60, 90, 120 and 150 days after treatment (DAT) for an assessment of herbaceous competition control and any symptomology of herbicide impact on the seedlings. In November 1998 and October 1999, seedling survival was recorded for each treatment plot. Competition control was recorded as percent clear ground with attention given to the principal species across the study area and any species, which occurred in the treatment plots.

RESULTS

At the end of the first growing season, only 3 of the herbicide treatments had an average survival, which was greater than the untreated plots (table 2). Overall survival across all plots was less than observed responses in other studies (Ezell 2000) and 2 factors are given credit for the lack of a positive treatment response and lower overall survival. First, the study site experienced severe drought conditions during the growing season, and it is probable that the shading provided by the competition may have benefited the seedlings in the untreated areas. Second, herbivory by deer was greater in the treated plots, as the open areas created by the treatment bands facilitated the movement of the animals and they occasionally browsed the seedlings as they moved through the area. While this type of herbivory done would probably not have resulted in overt mortality, it may have been a factor in weakening seedlings, which were also stressed by the droughty conditions.

At no time during the evaluations did any of the seedlings exhibit any symptoms of herbicide damage. Thus, the mortality can not be related to a lack of crop tolerance, and these products can be considered safe to use on Shumard oak as they were applied in this study, Even though first year survival was not as high as desirable, all treatments had acceptable survival except Trt. #7 and while 52.8 percent survival would result in marginally sufficient stocking for management, greater survival is expected when herbaceous weeds are controlled following proper plating operations.

Survival at the end of the second growing season provided interesting results. Generally average survival was slightly lower for treatments with 2 exceptions. Survival in Trt. #3 (5.6 oz of Sceptor 70 dg) was actually higher at the end of the second season than was recorded after the first growing season. This was due to resprouting of seedlings, which were necrotic from ground level and above in 1998 and were recorded as mortality at that time. Widely scattered occurrence of this resprouting was noted in other treatments, but not to the extent as found in Trt. #3 plots.

Survival in the untreated plots (Trt. #8) was drastically reduced at the end of the second growing season (table 2). The overall reduction of 77.8 percent (1998) to 44.4 percent (1999) represents a 43 percent change in these areas and was representative of what was occurring across the larger operational area outside the research plots. While the competing vegetation may have provided some shading during the first growing season, it also established a root system, which competed for any available soil moisture. While no indices of competing vegetation were undertaken in 1999, it seems that the trees in the treated plots were better able to establish a root system during the first growing season and were subsequently better able to compete for soil moisture during 1999. Land managers would do well to note that first year survival of planted oak seedlings in areas not receiving herbaceous competition control may not be indicative of “final establishment” survival.

SUMMARY

Six of the 7 herbicide treatments resulted in average survival, which was significantly greater than the untreated areas by the end of the second growing season. None of the treatments caused any damage to any oak seedlings and are considered safe to use. However, as of 2001, only OUST® and Goal 2XL® have labels for operational applications as were conducted in this study. Good seedlings and proper planting will always be important factors in obtaining desirable levels of initial survival of planted oak seedlings, and herbaceous weed control can result in significant benefits. Without herbaceous weed control, the cost and effort of properly planting high quality oak seedlings may not be enough to achieve desirable survival rates.

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RESPONSE OF PLANTED ROYAL PAULOWNIA TO WEED CONTROL TREATMENTS AFTER COPPICE

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Abstract—Today there is an increased interest in growing royal paulownia (*Paulownia tomentosa*) in the southeastern United States, but difficulties have been encountered in the Piedmont due to heavy clays and intense competition for moisture. Two royal paulownia plantations were established on the Virginia Piedmont to evaluate the effects that weed-mats have on tree survival and growth. The trees with weed-mats on the first plantation, an upland site, had 28 percent greater survival, were 2.8 feet taller, and had .9 inch greater diameter at breast height (dbh) at 4 years after coppice than the trees with no weed-mats. The trees with weed-mats on the second plantation, a bottomland site, had 10 percent greater survival, were 1.6 feet taller, and had .2 inch greater dbh at 4 years after coppice than the trees with no weed-mats.

INTRODUCTION

Today, there is growing interest in growing and managing paulownia plantations in the southeastern United States (Kays and others 1998). Royal paulownia (*Paulownia tomentosa*)is a pioneer species that was introduced into the United States approximately 160 years ago (Hu 1959). Royal paulownia is also known as the kiri tree, empress tree, and the princess tree. Paulownia wood is light in color, has a low density, and dries quickly without warping or cracking. Royal paulownia is easy to recognize by its large heart shaped leaves, its purple flowers, and large number of seed-pods present in mature trees. This tree is known for its rapid growth and ability to grow on a variety of sites. However, difficulties have been encountered in the Piedmont due to heavy clay soils and intense competition for moisture. Site preparation treatments can be used to break up the heavy clay soils, while herbicide and/or weed-mats can be used to control competition. The purpose of this study is to quantify the effects that weed-mats have on royal paulownia growth and survival in the Virginia Piedmont.

METHODS

In the spring of 1994, two royal paulownia plantations were installed near Virginia Tech's Reynolds Homestead Forest Resources Research Center located in the Piedmont physiographic province in Patrick County, VA. One plantation was on an upland (ridge-top) site, while the other was located on a bottomland site (floodplain). Each site was bedded before planting. Soil samples were collected from each plantation for characterization purposes. Ten push tube samples of the top 10 inches were collected and composited for each plantation. The soils were air dried and ground to pass a 2 mm sieve. The soils were then analyzed for total nitrogen and total carbon. Particle size analysis and pH were also determined. Containerized seedlings were planted in the spring of 1994. A 3ft by 3ft weed-mat was put around half of the trees at each site, while the other half were untreated. Herbicide applications of a 1.5 percent solution of glyphosate were applied around all trees each year. The trees were coppiced in the spring of 1997 after 3 growing seasons. Tree survival, tree heights, and diameters were recorded each November for five years (1996-2000). Weed-mat treatment effects on ground line diameter (GLD), height, diameter at breast height (DBH), and volume were analyzed by t-tests at the .10 level.

RESULTS AND DISCUSSION

Soil Characterization

Soil chemical and physical properties for both sites are presented in table 1. The upland site had a much higher coarse fragment content and a higher clay percentage than the bottomland site. The bottomland site has much higher levels of nitrogen and organic matter than the upland site. Sites with clay contents greater than 30 percent should be

Table 1—Soil chemical and physical properties for the upland and bottomland sites in Patrick County, VA

Site properties	Upland	Bottomland
Coarse fragment(%)	41	3
Sand(%)	39	38
Silt(%)	27	48
Clay(%)	34	14
Textural class	clay loam	loam
pH	5.31	5.67
Total N(ppm)	783	1338
Estimated N(lbs/ac)	1355	3222
Organic matter(%)	1.90	2.89

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Table 2-–Royal paulownia seedling performance for the upland site in Patrick County, VA

Variable	Treatment	Year[a] 1996	1997	1998	1999	2000
Survival(percent)	Weed-mat	51	51	50	50	50
	No weed-mat	23	23	23	23	22
GLD (in)	Weed-mat	2.4a	1.9a	8.5a	4.4a	5.3a
	No weed-mat	1.9b	1.6b	6.6b	3.4a	4.4a
DBH (in)	Weed-mat				3.1a	3.8a
	No weed-mat				2.6b	2.9b
Height (ft)	Weed-mat		7.5a	14.2a	19.6a	23.6a
	No weed-ma		6.2b	11.8a	16.7a	20.8a
Volume (ft^3)	Weed-mat		0.24a	1.4a	1.5a	2.7a
	No weed-mat		0.19a	0.9a	1.0a	2.0a

[a] Means within a column followed by the same letter are not significantly different at the 0.10 level.

Table 3-–Royal paulownia seedling performance for the bottomland site in Patrick County, VA

Variable	Treatment	Year[a] 1996	1997	1998	1999	2000
Survival(percent)	Weed-mat	55	55	46	40	37
	No weed-mat	40	40	36	32	27
GLD (in)	Weed-mat	2.2a	1.4a	2.2a	2.8a	3.5a
	No weed-mat	2.1a	1.3a	1.9b	2.4b	3.0b
DBH (in)	Weed-mat				2.0a	2.4a
	No weed-mat				1.8b	2.2a
Height (ft)	Weed-mat		5.6a	10.7a	13.8a	15.4a
	No weed-mat		5.2a	14.2a	12.8a	13.8a
Volume (ft^3)	Weed-mat		0.15a	0.56a	0.56a	0.89a
	No weed-mat		0.12a	0.44a	0.44a	0.69a

[a] Means within a column followed by the same letter are not significantly different at the 0.10 level.

avoided for paulownia plantations (Kays and others 1998), but site preparation treatments such as bedding or trenching can be used to ameliorate the effects of heavy clays by providing an improved rooting medium. The upland site is more typical of abandoned agricultural land in the Piedmont that would be planted to paulownia.

Seedling Performance

Seedling survival and growth were measured for five growing seasons, 1996 to 2000. Variables measured include percent survival, ground-line diameter (GLD), diameter at breast height (DBH), total height, and seedling volume expressed as diameter squared times height. In 1996, only GLD and survival data was collected. The 1999 growing season was the first year that DBH data was collected.

Upland Site—The means for the upland site are presented in table 2. The trees with weed-mats had 50 percent survival in the year before coppice, while the trees without weed-mats had only 23 percent survival (table 2). Survival did not vary substantially after the third growing season. Royal paulownia is highly dependent on adequate soil moisture for rapid growth (Beckjord 1991). Factors that influenced survival at this site were drought, late frosts, and disease. The weed-mats reduced competing vegetation, and thereby conserved water. High competition for moisture gave the trees with weed-mats an advantage which may have lessened the damage done by late frosts and disease.

Significant differences in GLD's were found for 1996, 1997, 1998, but not for 1999 and 2000. However, significant differences for DBH's were found for 1999 and 2000 suggesting that early GLD response leads to increased DBH growth in later years. In the fourth year after coppice (2000), the mean DBH was 0.9 inches larger for trees with weed-mats (table 2). A significant difference in height was found for only the first year after coppice, but 4 years after coppice the mean height was 2.8 feet taller for trees with weed-mats(table 2). No significant differences were found for volumes. Four years after coppice, the trees with weed-mats had 35 percent greater volume than trees without weed-mats.

Bottomland Site—The means for the bottomland site are presented in table 3. Tree survival slowly declined from 1997 to 2000. This site initially had higher survival than the upland site, but was more prone to multiple late spring frosts and deer damage. Late frosts killed back initial flushes at least once each year. Deer damage at this site included girdling the trees, as well as breaking the stem in some cases. The trees with weed-mats had 37 percent survival while trees without weed-mats had only 27 percent survival at four years after coppice (table 3). This site is a good example of how important site selection is when considering planting royal paulownia. The soils at this site would indicate royal paulownia should grow very well, but due to its topographic position and susceptibility to frost damage, this was a poor site selection.

Significant differences in GLD's were found for 1998,1999, and 2000. In addition, DBH's were found to be significantly different for 1999, but not for 2000. In the fourth year after coppice (2000), the mean DBH was .2 inches larger for trees with weed-mats (table 3). No significant differences were found for tree heights or volumes. However, trees with weed-mats were 1.6 feet taller and had 29 percent more volume than trees without weed-mats.

CONCLUSION

The establishment of a royal paulownia plantation on the Virginia Piedmont can best be described as difficult. On these sites, late frosts, drought, disease, and deer damage reduced overall survival and growth. This study does however suggest that weed-mats are beneficial and improve tree survival and growth. The trees with weed-mats on the upland site had DBH's that were 31 percent larger, heights 13 percent greater, and a survival rate that was more than twice that for trees having no weed-mats. The trees with weed-mats on the bottomland site had DBH's that were 9 percent larger, heights 12 percent greater, and survival that was 10 percent greater than the trees without weed-mats. Weed-mats can be a useful tool for the establishment of a productive royal paulownia plantation.

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